Field volatility of Dicamba

Report:	MRID 51017501. Toth, B.N. and L.B. Sisco. Off-target Movement Assessment of a Spray Solution Containing MON 76980 + MON 79789 + Intact™ – Mississippi. Unpublished study performed by Stone Environmental, Inc., Montpelier, Vermont; Eurofins EAG Agroscience, LLC, Columbia, Missouri; and AGVISE Laboratories, Northwood, North Dakota; sponsored and submitted by Monsanto Company, Chesterfield, Missouri. Stone Study ID: 19-038-A. Monsanto Study ID: STC-2019-0031. Reference No.: MSL0030827. Experiment initiation June 22, 2019 and completion July 16, 2019 (p. 7). Study and Report completion January 9, 2020.
Document No.:	MRID 51017501
Guideline:	OCSPP 835.8100 and 840.1200
Statements:	The study was completed in compliance with FIFRA GLP standards (40 CFR 160) with the exception of test site observations, slope estimates, application summary and spray rate data, soil taxonomy, calibrator serial numbers, filter paper deployment and collection times, study weather data, and pesticide and crop history (p. 4). Signed and dated Data Confidentiality, GLP Compliance, Quality Assurance, and Authenticity Certification statements were provided (pp. 2, 4, 5, and 9).
Classification:	This study is **supplemental**. A storm event occurred on Day 2, affecting the volatility and plant effects measurements.
PC Code:	128931
Final EPA Reviewer:	Chuck Peck Senior Fate Scientist Signature: 2020.10.24 18:53:40 -04'00' Date:
Final EPA Reviewer:	Frank T. Farruggia, Ph.D. Senior Effects Scientist Signature: 2020.10.25 12:50:00 -04'00' Date:
CDM/CSS-Dynamac JV Reviewers:	Richard Lester Environmental Scientist Signature: Date: 3/13/20 Joan Gaidos Environmental Scientist Signature: Date: 3/20/20

This Data Evaluation Record may have been altered by the Environmental Fate and Effects Division subsequent to signing by CDM/CSS-Dynamac JV personnel. The CDM/CSS-Dynamac Joint Venture role does not include establishing Agency policies.

Executive Summary

Field volatilization of dicamba formulation MON 76980, tank mixed with glyphosate potassium salt (MON 79789) and Intact™ (polyethylene glycol, choline chloride, and guar gum), was examined from a single dicamba-tolerant soybean-cropped test plot surrounded by non-dicamba tolerant soybean in Washington County, Mississippi. Vapor sampling and spray drift deposition sampling were conducted for *ca.* 168 hours following application. The products were applied at a nominal rate of 0.5 lbs. a.e./A. The study also examined off-target movement due to volatility and spray drift and resulting impacts to non-target plants. A control plot was established upwind of the test plot for plant effects. No control plot was established for field volatilization measurements.

Air temperatures, surface soil temperatures, and relative humidity the day of and after application ranged from 19.5-34.6°C (67.1-94.3°F), 21.7-46.9°C (71.1-116.4°F), and 56-98%, respectively. A thunderstorm occurred during the 24 to 48-hour post-application sampling period, with heavy rain (4.37 inches), such that volatility and deposition samples were either not collected, or were non-detect for periods 5-9 after application, resulting in uncertainty during these sampling periods.

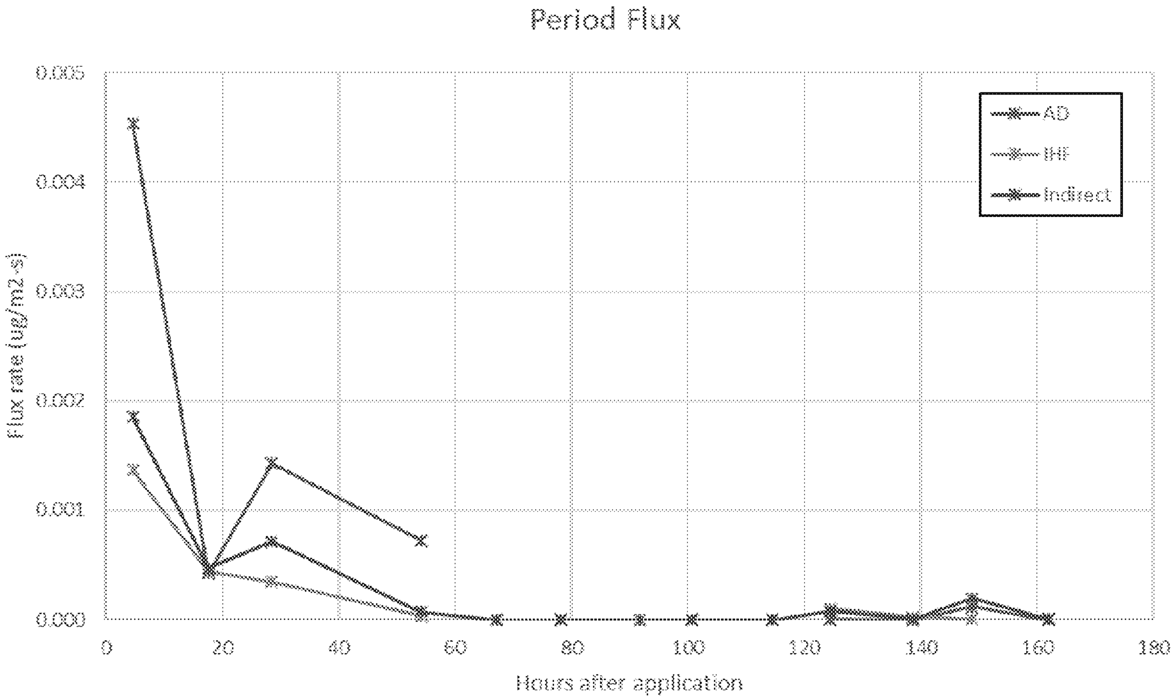
Under field conditions at the test plot, based on calculations using the Indirect method, a peak volatile flux rate of 0.001855 $\mu g/m^2 \cdot s$ was estimated by the reviewer, accounting for 0.048% of the applied dicamba observed 0.6 to 4.7 hours post-application. By the end of the study, the reviewer estimated that a total of 0.176% of dicamba volatilized and was lost from the field. Study authors estimated a peak flux rate of 0.00313 $\mu g/m^2 \cdot s$ at 0.6 to 4.7 hours post-application, with a cumulative loss of 0.216% of dicamba. Peak and secondary peak volatile flux rates occurred during warm daytime hours.

Under field conditions at the test plot, based on calculations using the Integrated Horizontal Flux method, a peak volatile flux rate of 0.001369 $\mu g/m^2 \cdot s$ was estimated by the reviewer, accounting for 0.027% of the applied dicamba observed 0.8 to 3.9 hours post-application. By the end of the study, the reviewer estimated a total of 0.104% of dicamba volatilized and was lost from the field. Study authors estimated a peak flux rate of 0.001406 $\mu g/m^2 \cdot s$ at 0.8 to 3.9 hours post-application, with a cumulative loss of 0.100% of dicamba.

Under field conditions at the test plot, based on calculations using the Aerodynamic method, a peak volatile flux rate of 0.004534 $\mu g/m^2 \cdot s$ was estimated by the reviewer, accounting for 0.088% of the applied dicamba observed 0.8 to 3.9 hours post-application. By the end of the study, a total of 0.348% of dicamba volatilized and was lost from the field. Study authors estimated a peak flux rate of 0.003920 $\mu g/m^2 \cdot s$ at 0.8 to 3.9 hours post-application, with a cumulative loss of 0.233% of dicamba.

Spray drift measurements indicated that dicamba residues were not detected in any of the upwind samples at one hour after application and were detected at a maximum fraction of the amount applied of 0.002638 in downwind samples and 0.002904 in left wind samples. Although approximately 1.33 acres, located near the upwind portion of the treated field, were left untreated as the sprayer ran out of test substance, the wind during the application blew away from the upwind samplers, minimizing uncertainty that the lack of residues in the upwind transects was due to this missing treated area. Deposition of dicamba above the NOAEC was detected in all transects of the downwind and left wind directions in the one-hour sampling period. Study authors estimated distances from the edge of the field to reach NOAEC for soybean (2.6×10^{-4} lb ae/A, or a deposition fraction of 5.2×10^{-4}) ranged from 5.2 to 13.2 m in the downwind direction and 7.4 to 15.2 m in the left wind direction. Reviewer-estimated distances were 9.4 m (7.7 to 10.4 m for the three transects) and 8.5 m (6.6 to 11.5 m for the two transects) in the downwind and left wind directions, respectively.

Figure 1 Volatile flux – Soybean Plot



<u>**Plant effects (51017501, EPA Guideline 850.4150; Supporting files in Appendix 2)**</u>

The effect of **MON 76980 (a.i. Dicamba diglycolamine (DGA) salt) + MON 79789 (a.i. Glyphosate potassium salt) + Adjuvant Intact^{TM}** on the vegetative vigor of dicot (soybean, *Glycine max)* crops was studied in a spray drift and volatilization study. Nominal test concentrations of Dicamba were 0.50 lb ae/A and Glyphosate were 1.125 lb ae/A. Dicamba test concentrations were analytically confirmed by monitoring field filter collectors during spray application as well as measurement of pre-application tank solutions; nominal and measured application rates are provided in Table 4. On day 28 the surviving plants along several transects projecting from the treated area were measured for height.

<u>Spray Drift + Volatility Study</u>

Dicamba-non-tolerant soybean were observed at distances of approximately 3, 5, 10, 20, 40, 50, 60 and 90 meters from the edge of the treatment application field in the downwind, upwind, and lateral directions. Height effects and visible signs of injury (VSI) were recorded up to 28 days after spray application of the tank mix.

Regression based distances to a 5% reduction in plant height were evaluated for each individual transect. The plant height data from control plots were used to establish the baseline 5% effect level plant height.

Visible symptomology was reported, but the specific phytotoxic symptoms were not. VSI distances were established based on regression estimated distances to a 10% VSI. For the drift study, three of the downwind transects, two of the left wind transects, and the east diagonal transect showed a dose-response relationship between percent of visual symptoms and distance to the treatment field. Percent of visible symptoms was a maximum of 50% at 4 m and for several transects VSI exceeded 10% at 90 m.

Furthest distance to 5% Reduction in Plant Height = 67.3 meters (220.8 feet)
Furthest distance to 10% VSI = 109 meters (357.6 feet)

Volatility Study

Dicamba-non-tolerant soybean were planted in test plots at distances of approximately 3, 5, 10, and 20 meters from the edge of the treatment application field in the downwind, upwind, and lateral directions and isolated using plastic sheeting (transect covers) during the application period to prevent exposure to spray drift. Height effects and visual symptomology was recorded up to 28 days after spray application of the tank mix.

When compared to the negative control plot, the study author and reviewer found significant inhibitions in plant height along several transects. Several transects observed 10% or greater VSI across the entire transect length.

Furthest distance to 5% Reduction in Plant Height = 16.0 meters (52.5 feet)
Furthest distance to 10% VSI = >20meters (>65.6 feet)

Table 1. Estimated distances to regulatory threshold responses for reductions in plant height and visible signs of injury.

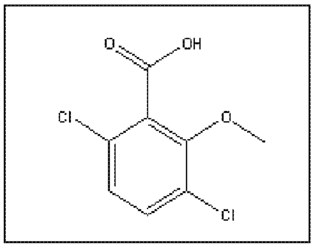
Exposure Pathway	Spray Drift + Volatility (uncovered transects)		Volatility (covered transects)	
Transect	Distance to 5% Height (meters)	Distance to 10% VSI (meters)	Distance to 5% Height (meters)	Distance to 10% VSI (meters)
DWA[a]	56.2[e]	109.0[c]	13.7[e]	>20[f]
DWB[a]	58.8[e]	91.8 [b,d]	16.0[e]	>20[f]
DWC[a]	67.3[e]	>90 [b,f]	-	-
LWA	16.1[e]	48.7[e]	<5[f]	<3[f]
LWB	11.1[e]	50.4 [c]	>5[f]	<3[f]
NE	22.1[e]	44.0 [e]	-	-
RWA	<10[f]	<3[f]	2.8[e]	<3[f]
RWB	<10[f]	<3[f]	7.8[e]	<3[f]

SE	<10[f]	<3[f]	-	-
SW	>60[f]	<3[f]	-	-
UWA	<10[f]	<3[f]	<5[f]	<3[f]
UWB[a]	>60[f]	>90[b,f]	12.2[e]	>20[f]

[a] Study authors indicate flooding may have impacted these transects
[b] DWC Injury showed a shallow dose response with effects ranging from 50% at 5 meters to 35% at 90 meters. UWB injury ranged from 20-25% for the extent of the transect.
[c] distance estimated with linear regression
[d] distance estimated with polynomial regression
[e] distance estimated with logistic regression
[f] distance estimated visually

I. Materials and Methods

A. Materials



1. Test Material

Product Name: MON 76980 (Appendix B, pp. 100-101)
Formulation Type: Liquid
CAS #: 104040-79-1
Lot Number: 11495284
Storage stability: The expiration date of the test substance was May 10, 2020.

Product Name: MON 79789
Formulation type: Liquid
CAS Number: 70901-12-1
Lot Number: 11495283
Storage stability: The expiration date of the test substance was May 7, 2020.

Product Name: Intact
Formulation type: Liquid
CAS Number: 25322-68-3
Lot Number: 0831B037000 (Batch# 374-25)
Storage stability: The expiration date of the test substance was May 8, 2022.

2. Storage Conditions

The test substances were received on May 9, 2019 and stored at Stoneville R&D, Inc., Greenville, Mississippi (Appendix B, p. 101). The test substances were sprayed on the test plot on June 22, 2019 (p. 13). The study protocol indicates the test substance would be stored under label conditions in a monitored pesticide storage area adequate to preserve stability (Appendix A, p. 40).

B. Study Design

1. Site Description

The test site was located in Washington County, Mississippi, *ca.* 6.5 miles east of the Mississippi River and *ca.* 5 miles southwest of Leland, Mississippi (Appendix B, p. 102). A single soybean-cropped field, measuring *ca.* 340 m × 300 m (~25 A) was treated with a mixture of MON 76980 (containing dicamba), MON 79789 (containing glyphosate potassium salt), and Intact™ (polyethylene glycol, choline chloride, and guar gum). The crop on the plot was a dicamba-tolerant soybean crop (Variety: AG45X8, Lot: HU8SEC1B) with a 110-ft buffer surrounding the plot planted in non-tolerant soybeans (Variety: NKS45-W9, Lot: 14287759). Soil characterization indicated the USDA textural class was clay (Appendix B, pp. 125). Prior to the study, dicamba had not been applied to the test plot within the previous three years (Appendix B, pp. 104-105). Crop history for the three years preceding the study indicated the field had been planted in soybean (Appendix B, pp. 164-171). Dicamba was applied to the field to the north of the test plot on June 15, 2019, exactly one week prior to the start of the study, with winds from the south. Dicamba was applied to the field east of the test plot three weeks prior to the study (Appendix B, p. 105). Terrain was flat with a slope between 0 and 1%. The test plot was surrounded by agricultural land (Appendix B, Figure 1, p. 143) and had a low berm running north to south through the east side of the field. The test plot and surrounding buffer zone were planted with soybean on April 29, 2019 and replanted on May 24, 2019 as a result of seed damage due to heavy rain and flooding (Appendix B, p. 103). The soybean seeds were planted at a density of 134,000 seeds/A on 30-inch row spacing for both plantings.

2. Application Details

Application rate(s):	The target application rate was 0.5 lb a.e./A or 15 GPA (p. 14; Appendix A, p. 41; Appendix B, p. 104). Four application monitoring samples consisting of four sets of four circular filter paper samples each were positioned in the spray area in locations to capture various portions of the spray boom (Appendix B, p. 109). The spray rate was automatically maintained by a variable rate controller (Appendix B, p. 116). The application rate was assumed to be 100% of the target rate. Based on Climate FieldView™ software, the actual application rate was 103% of the target application rate or 15.4 GPA (Appendix B, Table 1, p. 123). The final infield pass (1.33 acres of the plot, upwind side of field) was unsprayed due to a calculation error (Appendix B, p. 106). Transects UWA and LWA would have been most impacted.
Irrigation and Water Seal(s):	No irrigation or water seals were reported in the study. A storm event totalling 4.37 inches of precipitation occurred on June 23 and 24, 2019 (Appendix B, pp. 137-138). A total of 4.90 inches of

precipitation were reported during the seven-day field volatility study.

Tarp Applications: Tarps were not used on the test plot. Tarps were used on nine plant effects transects before application, during application, and for as long as 2 hours 10 minutes following application. These tarps were intended to prevent exposure to spray drift to assess secondary movement only (volatility; Appendix A, pp. 46 and 66). Study authors attribute long tarp covering (was supposed to be less than 30 minutes) and high heat as contributing factors to cause heat stress to these plots.

Application Equipment: A Case IH Patriot 3230 ground sprayer equipped with a 90-ft boom was used for the spray application (Appendix B, p. 104). 54 Turbo TeeJet® Induction nozzles (TTI 11004) were installed with 20-inch spacing and the boom height was set at 20 inches above the crop canopy (soybeans were 17 cm at time of spraying). The sprayer had one spray tank with a volume of 800 gallons.

Equipment Calibration Procedures: Nozzle uniformity was tested by spraying water at a pressure of 63 psi through the boom and measuring nozzle output using SpotOn® Model SC-1 sprayer calibrator devices (Appendix B, p. 104). Each nozzle was tested three times to determine variability. Calibration of the sprayer and nozzles established the total boom output per minute of spray to be 26.1 GPM. The forward speed of the sprayer tractor was calibrated by timing the duration required, in seconds, to drive a known distance of 1,320 ft. Speed verification was repeated two times with three runs per speed verification for a total of six tractor runs.

Application Regime: The application rates and methods used in the study are summarized in **Table 2**.

Table 2. Summary of application methods and rates for dicamba

Field	Application Method	Time of Application (Date and Start Time)	Amount Dicamba Applied[1] (lbs)	Area Treated[2] (acres)	Calculated Application Rate[3] (lb ae/acre)	Reported Application Rate (gal/acre)
Soybean	Spray	6/22/2019 at 14:15	12.2	23.67	0.515	15.4

Data obtained from Appendix B, p. 106 and Appendix B, Table 1, p. 123 of the study report.

[1] Reviewer calculated as calculated application rate (lb a.e./acre) × area treated (acres).

[2] Area treated is the area of the field (*ca.* 25 acres) minus the area untreated due to running out of tank mix (*ca.* 1.33 acres).

[3] Reviewer calculated as percent of target applied (103%) × target application rate (0.5 lb a.e./acre, Appendix B, p. 119).

Application Scheduling: Critical events of the study in relation to the application period are provided in **Table 3**.

Table 3. Summary of dicamba application and monitoring schedule

Field	Treated Acres	Application Period	Initial Air/Flux Monitoring Period[1]	Water Sealing Period	Tarp Covering Period[2]
Soybean	23.67	6/22/2019 between 14:15 – 14:38	6/22/2019 between 14:51 – 18:54	Not Applicable	6/22/2019 Between 13:45-15.55

Data obtained from Appendix B, p. 106; Appendix B, Table 5, p. 127; and Appendix B, Table 7, p. 131 of the study report.

[1] Initial air monitoring period is that for perimeter stations. The initial period at the center station was 6/22/2019 between 15:05 – 18:07.

[2] Tarps were placed on select transects to evaluate volatility exposure without spray drift. Note that tarps remained on the field for 2+ hours, significantly beyond the 30-minute post application window.

3. Soil Properties

Soil properties measured before the study are provided in **Table 4**. pH of the soil was 7.3 (Appendix B, Table 3, p. 125).

Table 4. Summary of soil properties for the soybean plot

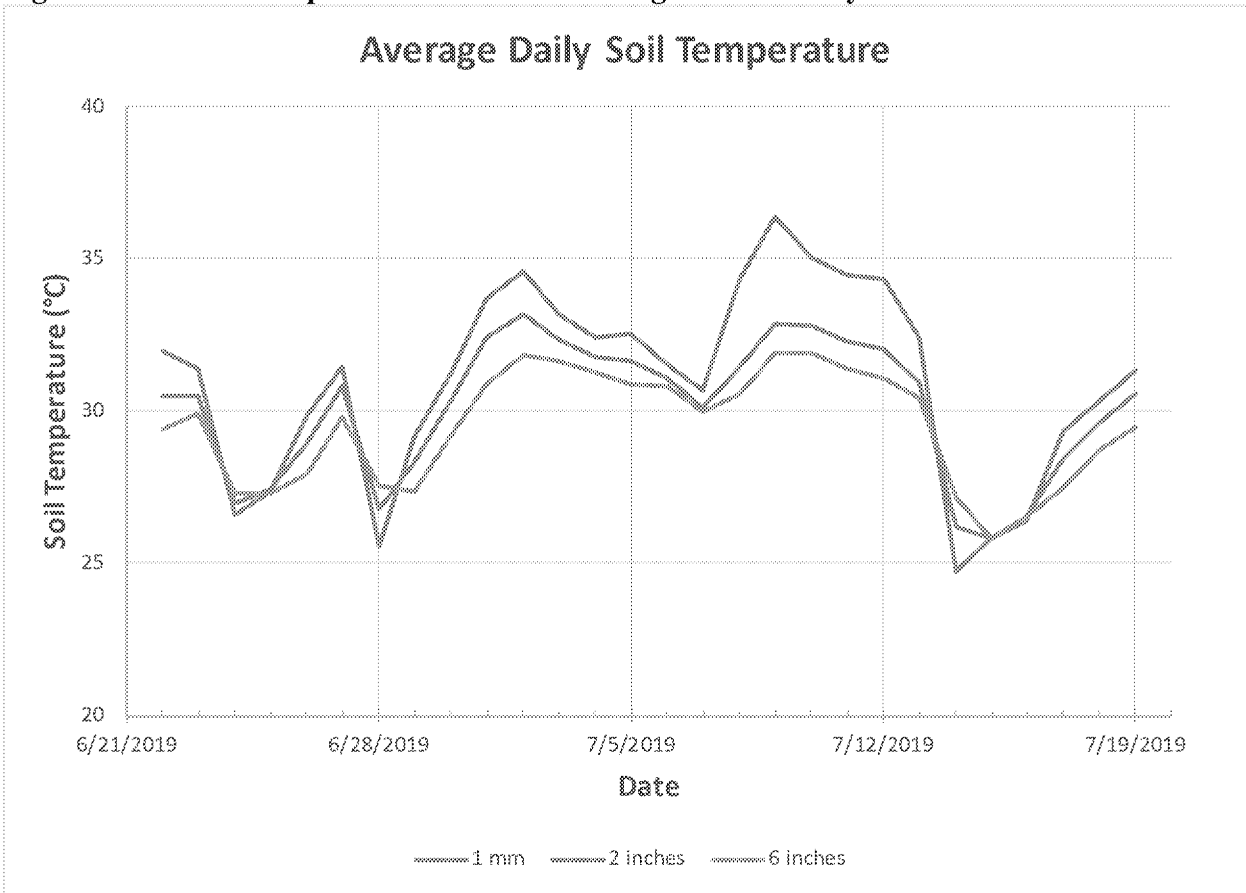
Field	Sampling Depth (inches)	USDA Soil Textural Classification	USGS Soil Series	WRB Soil Taxonomic Classification	Bulk Density (g/cm^3)	Soil Composition
Soybean	0-6	Clay	Not Reported	Not Reported	1.05	% Organic Carbon[1] = 1.22% % Sand = 21% % Silt = 20% % Clay = 59%

Data obtained from Appendix B, pp. 108, 117-118, and Appendix B, Table 3, p. 125 of the study report.

[1]Reviewer calculated as: organic carbon (%) = organic matter (%)/1.72. Organic matter was reported as 2.1%.

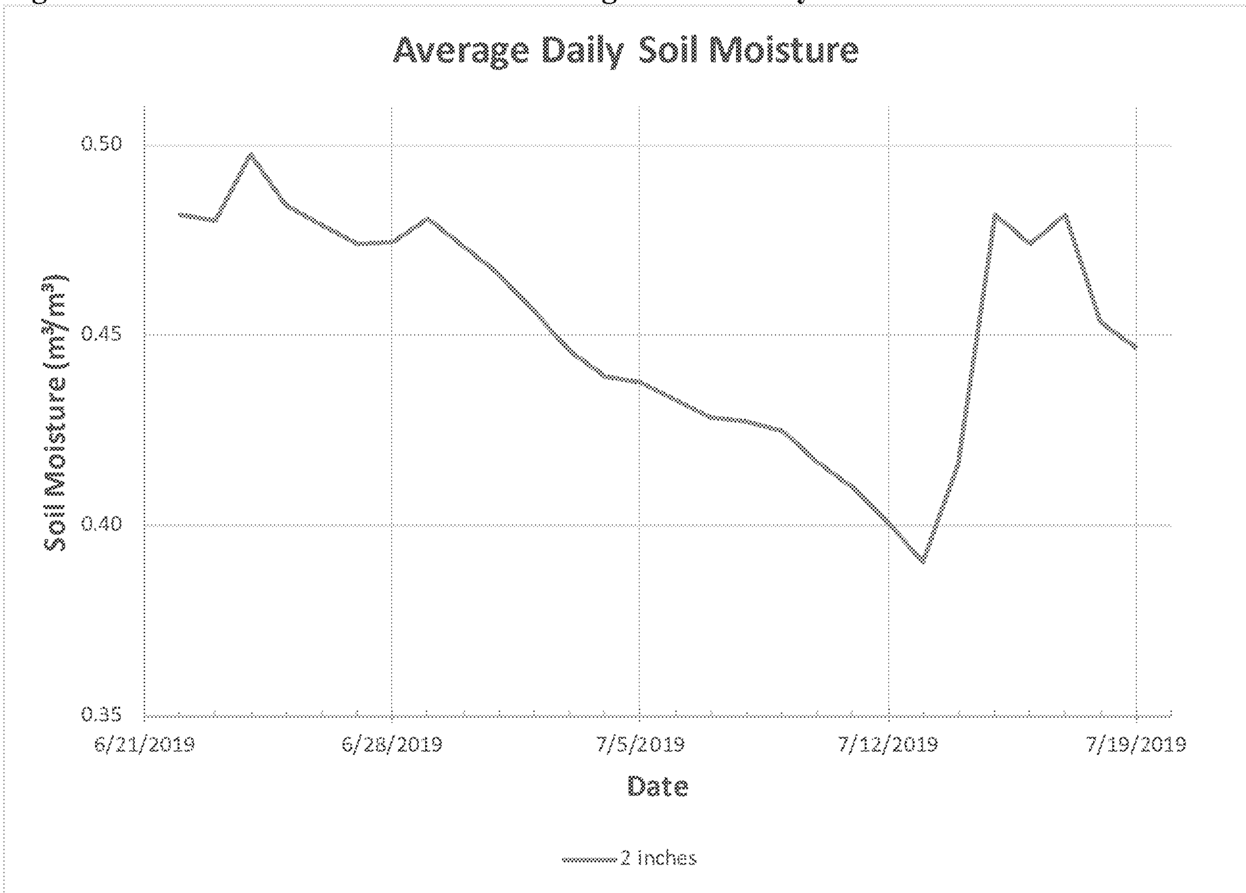
Figures 2 and 3 are plots of soil temperature and soil moisture measured throughout the study.

Figure 2 Soil temperature measured throughout the study



Data obtained from Appendix B, Table 13, pp. 139-140 of the study report.

Figure 3 Soil moisture measured throughout the study



Data obtained from Appendix B, Table 13, pp. 139-140 of the study report.

4. Source Water

Tank mix water was obtained from well water from GT&T Farms. The pH of the tank mix water was 8.6 with an alkalinity of 270 mg $CaCO_3$/L and a conductivity of 0.63 mmhos/cm.

5. Meteorological Sampling

Five meteorological stations were used to collect weather data during the study (Appendix B, p. 106).

The 10-meter main meteorological station was located upwind of the test plot (Appendix B, p. 106, and Figure 2, p. 144). The system included a Campbell CR6 data logger and a Campbell Scientific Cell 210 module to remotely monitor data. All parameters were reported at heights of 1.7, 5, and 10 m. The station included sensors for monitoring windspeed and direction (3D anemometer at 10 m and 2D anemometers at 1.7 and 5 m), air temperature, and relative humidity.

A boom height anemometer collected wind speed and wind direction data during application at a height of 68 cm (27 in) above the soil surface (Appendix B, p. 107). The anemometer was located *ca.* 3 m downwind of the sprayed area.

The long duration main meteorological station was located upwind of the test plot and recorded data for 28 days post-test substance application (Appendix B, p. 107, and Table 13, pp. 139-140). The station included wind speed and direction sensors (1.7 m), a rain gauge sensor (1.5 m), a temperature/relative humidity sensor (1.16 m), a pyranometer to measure solar irradiation (1.5 m), three soil temperature sensors (depths of 1 mm, 2 inches, and 6 inches), and one soil moisture sensor (depth of 2 inches).

The primary flux meteorological station was deployed outside of the plot prior to and during application and was then moved to the center of the plot, remaining there until three hours after the final drift sample was collected on June 29, 2019 (Appendix B, p. 107). The station included a Campbell CR6 data logger and a Campbell Scientific Cell 210 module to remotely monitor data. The station included sensors for air temperature, relative humidity, wind speed, and wind direction at heights of 0.33, 0.55, 0.9, and 1.5 m above the crop canopy.

A secondary flux meteorological station also recorded air temperature, relative humidity, wind speed, and wind direction at heights of 0.33, 0.55, 0.9, and 1.5 m above the crop canopy (Appendix B, p. 107). The secondary meteorological station was a backup flux meteorological station and was positioned upwind and outside of the sprayed area.

Details of the sensor heights and the meteorological parameters for which data were collected are illustrated in **Table 5**. The location of the meteorological equipment is shown in **Attachment 3**.

Table 5. Summary of meteorological parameters measured in the field

Field	Minimum Fetch (m)	Parameter	Monitoring heights (m)	Averaging Period
Soybean Plot 10-Meter Main Met. Station	Not Reported	Air temperature	1.7, 5, and 10	1 minute
		Relative humidity	1.7, 5, and 10	1 minute
		Wind speed/wind direction	1.7, 5, and 10	1 minute
Soybean Plot Boom Height Anemometer	Not Reported	Wind speed/wind direction	0.68	Not Reported
Soybean Plot Long Duration Main Met. Station	Not Reported	Precipitation	1.5	1 minute
		Air temperature	1.16	1 minute
		Relative humidity	1.16	1 minute
		Soil temperature	1 mm, 2 in, 6 in depth	1 minute
		Soil moisture	2 in depth	1 minute
		Solar radiation	1.5	1 minute
		Wind speed/wind direction	1.7	1 minute
Soybean Plot Primary Flux Met. Station	158.84	Air temperature	0.33, 0.55, 0.9, and 1.5*	1 minute
		Relative humidity	0.33, 0.55, 0.9, and 1.5*	1 minute
		Wind speed/wind direction	0.33, 0.55, 0.9, and 1.5*	1 minute
Soybean Plot Secondary Flux Met. Station	Not Reported	Air temperature	0.33, 0.55, 0.9, and 1.5*	1 minute
		Relative humidity	0.33, 0.55, 0.9, and 1.5*	1 minute
		Wind speed/wind direction	0.33, 0.55, 0.9, and 1.5*	1 minute

Data obtained from Appendix A, pp. 49, 68; Appendix B, pp. 106-107; and Appendix D, Table 8, p. 557 of the study report.
* Denotes height above crop canopy

6. Air Sampling

Two pre-application samples were collected at 0.15 m above the crop surface at the approximate center of the test plot (Appendix B, p. 110). Samples were collected for *ca.* 6 hours on June 21, 2019 from 13:24 to 19:21.

Post-application in-field air samplers were used for flux monitoring for *ca.* 168 hours following application (Appendix B, pp. 110-111). Samplers were placed on a mast in the approximate center of the plot directly following spray application at heights of 0.15, 0.33, 0.55, 0.90, and 1.5 m above the crop surface. Samples were collected at *ca.* 6, 24, 36, 48, 72, 84, 96, 108, 120, 132, 144, 156, and 168 hours post-application. Because application occurred in the afternoon, a planned 6 to 12-hour sampling interval was removed from the sampling. The 0 to 6-hour sample was shortened based on the time remaining until sunset on the day of application, with subsequent samples being collected on a sunrise-sunset schedule. Due to wet sub-surface field conditions, the center mast sunk below its original position and the 12 to 24-hour post-application PUF samples were collected at heights 6 to 10 cm closer to the ground than intended. Due to unsafe weather conditions, a planned 48 to 60-hour sample was not deployed or collected.

Off the plot, eight perimeter air monitoring stations were located 1.5 m above the crop canopy and 5 m outside the edge of the plot (Appendix B, p. 111). Samples were collected at *ca.* 6, 24, 36, 48, 72, 84, 96, 108, 120, 132, 144, 156, and 168 hours post-application. The sampling schedule was the same as for the in-field air sampling. In addition, due to unsafe sampling conditions, perimeter volatility samples G and C were not deployed or collected for the 60 to 72-hour sampling period.

7. Spray Drift Monitoring

The spray drift test system consisted of three downwind transects, two left wind transects, two right wind transects, and two upwind transects (Appendix B, pp. 112-114). All transects were perpendicular to the edge of the field. Deposition collectors (Whatman #1 15 cm diameter filter papers) were placed on all transects at the following distances from the edge of the spray area: 3, 5, 10, 20, 40, 50, and 60 m. Deposition collectors were also placed at 90 m in the downwind transects only. Deposition collectors were secured to carboard squares and attached to a horizontal plastic platform at crop height. Initial deposition samples were collected 5 minutes after spray application was completed. Deposition samples were then collected at intervals of 1, 24, 72, 96, 120, 144, and 168 hours post-application. Deposition samples were not deployed or collected 24-48 hours after the application due to inclement weather.

8. Plant Effects Monitoring

The off-target movement of dicamba due to spray drift and volatility following the application of dicamba to dicamba tolerant soybeans was assessed by comparing plant heights and visual plant symptomology along transects of non-tolerant soybean crop surrounding the treated soybean field and perpendicular to the sprayed field edges of the application area, as well as three transects radiating from the corners of the sprayed field, out to a maximum distance of approximately 90 meters. A fourth diagonal transect was planned, however, due to the poor emergence in the downwind portion of the field, no data from northwest corner transect was collected. Transects were not located within pre-determined designated ingress and egress areas for the sprayer. Along with the plant effect transects located immediately adjacent to the treated field, six upwind control areas were identified and evaluated for plant height. (Appendix G, pp. 707-708)

Dicamba-non-tolerant soybean were evaluated at distances of approximately 3, 5, 10, 20, 40, 50, 60 and 90 meters from the edge of the treatment application field in the downwind, upwind, lateral, and diagonal directions. Height effects and visual symptomology was recorded at 0, 16, and 28 days after treatment.

Plant effects from volatility only were assessed by isolating a portion of the non-tolerant soybean crop immediately adjacent to the treated areas using plastic sheeting (transect covers) during the application period to prevent exposure to spray drift. The non-tolerant soybeans that were covered during the application were used to assess effects to plant height and visual symptomology from dicamba volatility. The plastic covers were intended to remain in place for approximately 30 min post-application before permanent removal for the remainder of the study; however, due to safety concerns for the field personnel (high heat and humidity) some of the covers remained covering the plants for significantly longer than the specified 30-min period. The actual time the plants remained covered ranged from approximately 1:45 to 3:55 pm (2 hours, 10 minutes) (Appendix G, p. 707). Transects for volatility only were 20 m long and plant height measurements and visual symptomology ratings were completed at approximately 3, 5, 10, and 20 m from the sprayed area at 0, 16, and 28 days after treatment.

Because of the variability in plant height and stand condition, actual measurement distances differed from the target distances for some transects; however, the actual distances were recorded and used for data analysis. At each distance along each transect, ten plants were selected non-systematically with no attempt to measure the same plant at the subsequent time points. Plant height was measured by holding a plant upright and measuring the distance between the ground and the tip of the most recently emerged apical bud to the nearest centimeter using a metal metric ruler. Where multiple shoots were present, measurements along the main shoot were taken.

9. Sample Handling and Storage Stability

PUF sorbent tube samples and deposition filter paper were handled with clean nitrile gloves, which were replaced after the collection of samples and prior to installation of a new sample media for the next sampling interval (Appendix B, pp. 108-109). PUF sorbent tubes and filter paper were placed in pre-labeled conical tubes. Pre-application and post-application PUF samples and all deposition samples were stored in separate freezers capable of storing samples at *ca.* -20°C freezer prior to shipment. Spray area (application monitoring) samples were kept separate from other samples and were stored and shipped in a cooler containing dry ice until final transfer to storage at approximately -20°C at the analytical test site. Tank mix samples were stored and shipped in a cooler under ambient conditions. Field spikes and transit stability samples were stored in coolers containing dry ice. All samples were shipped in coolers on dry ice via FedEx to the analytical test site, Eurofins, in Columbia, Missouri.

All field collected PUF and filter paper samples were extracted within 20 and 10 days, respectively, after collection. All field exposed QC and transit stability samples were extracted within 17 days after fortification. Stability of dicamba on PUF and filter paper samples was demonstrated for at least 78 and 85 days, respectively, during frozen storage in a stability study (Maher 2016). All PUF and filter paper samples were analyzed within 8 and 2 days, respectively, after extraction, which study authors indicate is within the demonstrated stability (Appendix C, p. 258-259).

10. Analytical Methodology

- Sampling Procedure and Trapping Material: Flux monitoring equipment consisted of PUF collectors and tubing protected from precipitation by ¾ inch diameter PVC pipes (Appendix B, p. 110). SKC AirChek 52 air sampling pumps were used, covered with plastic bags to protect them from precipitation. Pumps were calibrated to a flow rate of 2.950-3.050 L/min. Spray drift deposition collectors consisted of Whatman #1 15 cm diameter filter papers.

- Extraction method: The contents of the PUF sorbent tubes were extracted using methanol containing stable-labelled internal standard (Appendix C, pp. 313-336). The sample was fortified with internal standard, a grinding ball was added to the tube, and 29.8 mL of methanol was added. The sample tubes were capped and agitated on a high-speed shaker (Geno/Grinder®) for 1200 cycles per minute for 30 minutes. The cap was removed, and a 1.5 mL aliquot was transferred to a 0.45 µm polypropylene 96-well filter plate with a clean polypropylene plate positioned below the filter plate (Appendix C, pp. 337-338). The sample was evaporated to dryness under nitrogen at 50°C. The sample was reconstituted with 0.150 mL of 25% methanol in water. The sample was mixed and analyzed by LC-MS/MS with electrospray ionization in negative ion mode within the storage time determined during method validation (Appendix C, p. 258).

  The filter paper samples were extracted using methanol containing stable-labelled internal standard (Appendix C, pp. 341-356). The sample was fortified with internal standard, a grinding ball was added to the tube, and 29.8 mL of methanol was added. The sample tubes were capped and agitated on a high-speed shaker (Geno/Grinder®) for 1200 cycles per minute for 5 minutes. The tubes were then placed in a ≤10°C centrifuge (4500 xg for 5 minutes) and spun to clear suspended materials from the liquid column and form a solid pellet. The cap was removed and a 0.35 mL aliquot was transferred to a clean 96-well filter plate with a clean, glass-lined polypropylene plate positioned below the filter plate (Appendix C, pp. 348). The plates were then placed in a ≤10°C centrifuge (1500 xg for 1 minute) and spun until liquid passed through the plate. The solution was analyzed by LC-MS/MS with electrospray ionization in negative ion mode within the storage time determined during method validation (Appendix C, p. 348).

- Method validation (Including LOD and LOQ): Method validation was achieved by fortifying 18 replicate fortification samples at each of three fortification levels (0.3 ng/PUF, 3 ng/PUF, and 60 ng/PUF; Appendix C, pp. 331-335). Validation assessments showed acceptable accuracy between 70% and 120% and precision (<20% RSD) for all fortified matrices at each fortification level for both primary and secondary ion transitions. Average recoveries for primary ion transitions were 89%, 94%, and 90% at 0.3, 3, and 60 ng/PUF, respectively. Average recoveries for secondary ion transitions were 93%, 97%, and 98% at 0.3, 3, and 60 ng/PUF, respectively. No independent laboratory validation is provided. For primary ion transitions, the LOQ during method validation was 0.30 ng/PUF and the LOD was 0.094 ng/PUF (Appendix C, p. 332). For secondary ion transitions, the LOQ during method validation was 0.30 ng/PUF and the LOD was 0.065 ng/PUF. During the study, the LOQ was 1.0 ng/PUF (p. 19).

  Method validation was achieved by fortifying 6 replicate fortification samples at each of three fortification levels (0.005, 0.10, and 4.8 µg/filter paper; Appendix C, pp. 355). Validation assessments showed acceptable accuracy between 70% and 120% and precision (<20% RSD) for all fortified matrices at each fortification level for both primary and secondary ion transitions. Average recoveries were 81%, 117%, and 104% at 0.005, 0.10, and 4.8 µg/filter paper, respectively. No independent laboratory validation is provided, although results from Field Deposition Study REG-2015-004 confirmed the results. The LOQ during method validation was 0.005 µg/filter paper (Appendix C, p. 341). During the study, the LOQ was 0.005 µg/filter paper (p. 19).

- Instrument performance: Calibration standards were prepared at concentrations ranging from 0.15 to 75 ng/PUF (Appendix C, p. 319). Concentrations were 0.15, 0.225, 0.3, 0.75, 1.5, 2.25, 3, 7.5, 15, 22.5, 30, and 75 ng/PUF. Analyst® software was used to derive the calibration curve using a weighted linear curve (1/x; Appendix C, pp. 325 and 378).

  Calibration standards were prepared at concentrations ranging from 0.0015 to 6 µg/filter paper (Appendix C, p. 346). Concentrations were 0.0015, 0.003, 0.0075, 0.015, 0.03, 0.075, 0.15, 0.3, 0.75, 1.5, 3, and 6 µg/filter paper. Analyst® software was used to derive the calibration curve using a weighted quadratic curve (1/x; Appendix C, pp. 351 and 402).

11. Quality Control for Air Sampling

Lab Recovery: 19 of 24 laboratory spike recoveries are within the acceptable range of 90-110% (Appendix C, pp. 381-382). All laboratory spike recoveries are within the range of 84-117%. Laboratory spike samples were prepared at fortification levels of 1 ng/PUF (12 samples) and 60 ng/PUF (12 samples). Average recoveries were 100% and 98% at 1 ng/PUF and 60 ng/PUF, respectively (Appendix C, p. 382).

Field blanks: Two pre-application samples were collected from the center of the test plot from 13:24 to 19:21 on June 21, 2019, the day before application (Appendix B, p. 110). Dicamba was not detected in either pre-application sample (Appendix B, p. 118).

Control samples from the field spike analysis contained detectable dicamba in one of six control samples (Appendix B, pp. 118-119 and Appendix C, Table 8, p. 275). Dicamba was detected at a level of 1.80 ng/PUF in the one sample.

Field Recovery: Nine 6-hour and nine 12-hour field spike samples were collected at concentration levels of 3, 10, and 30 ng/PUF. A total of six field spikes were prepared at each concentration level. Most field spike recoveries are within the acceptable range with overall recoveries of 89% to 116% at 3 ng/PUF, 86% to 111% at 10 ng/PUF, and 94% to 116% at 30 ng/PUF (Appendix B, pp. 118-119).

Travel Recovery: Three transit stability PUF samples were fortified at 30 ng/PUF and placed on dry ice along with three unfortified control samples (Appendix B, p. 119). Dicamba was not detected in the control samples. The range of recoveries from the fortified samples was from 93% to 111%.

Breakthrough: Laboratory spike samples that were fortified at 60 ng/PUF had recoveries ranging from 88% to 109% (Appendix C, pp. 381-382). The highest dicamba amount measured on a PUF sample (excluding laboratory and field spikes) was 27.8 ng/PUF (Appendix C, pp. 385-393) which is *ca.* 46% of the highest fortification level, indicating that dicamba loss due to breakthrough is unlikely.

12. Quality Control for Deposition Sampling

Lab Recovery: 47 of 51 laboratory spike recoveries are within the acceptable range of 90-110% (Appendix C, pp. 381-382). All laboratory spike recoveries are within the range of 92-114%. Laboratory spike samples were prepared at fortification levels of 0.005 µg/filter (24 samples), 5 µg/filter (24 samples), and 50 µg/filter (3 samples). Average recoveries were 105%, 104%, and 103% at 0.005 µg/filter, 5 µg/filter, and 50 µg/filter, respectively (Appendix C, p. 401).

Travel Recovery: Five transit stability filter paper samples were fortified at 0.05 µg/filter paper and placed on dry ice along with five unfortified control samples (Appendix C, p. 162, 421). Dicamba was not detected in the control samples. The range of recoveries from the fortified samples was from 94% to 106%.

13. Application Verification

Four application monitoring sampling stations, each consisting of four 12.5 cm diameter Whatman #3 filter paper samples, were positioned in the spray area (Appendix B, pp. 109-110). The stations were positioned to capture different portions of the spray boom and different spray nozzles. Samples were collected approximately 5 minutes after spray application was complete. The average recovery relative to the target was 78% (Appendix B, p. 118).

Spray application rates were automatically maintained by the sprayer using a variable rate controller, allowing the sprayer to maintain the target application rate at varying speeds (Appendix B, p. 116). The application rate was assumed to be 100% of the target rate, and pass times were not used to calculate an application rate. Based on Climate FieldView™ software application data, the actual application rate was 103% of the target rate (Appendix B, p. 123).

Tank mix samples were also collected and analyzed to verify the amount of dicamba present in the tank mix (Appendix B, p. 109).

14. Deposition and Air Concentration Modeling

Off-target air concentrations and deposition were calculated based on the calculated flux rates and relevant meteorological data. U.S. EPA's AERMOD model (version 18081) was used to estimate vapor deposition, while the Probabilistic Exposure and Risk model for Fumigants (PERFUM2, version 2.5) was used to estimate air concentrations (Appendix E, p. 606).

Three sets of estimates were calculated, using meteorological data for Raleigh, North Carolina; Peoria, Illinois; and Lubbock, Texas (Appendix E, p. 607).

Wet, dry, and total deposition estimates were made at 10 distances from the field (5, 10, 20, 30, 40, 50, 75, 100, 125, and 150 m; Appendix E, pp. 609). For the fluxes from the soybean plot at a distance of 5 m from the edge of the field, the maximum 24-hour average total (dry+wet) deposition ranged from 7.78 to 9.50 $\mu g/m^2$ (Appendix E, Table 7, pp. 621-622). 90^{th} percentile total deposition ranged from 3.57 to 4.62 $\mu g/m^2$.

Modeled dicamba air concentrations were calculated at 4 distances from the field (5, 10, 25, and 50 m; Appendix E, pp. 608-609). Modeled 95^{th} percentile 1-hr air concentrations ranged from 59.2 to 107.5 ng/m^3 at 5 m from the edge of the treated field and 43.6 to 79.1 ng/m^3 at 50 m from the edge of the field. Modeled 95^{th} percentile 24-hr air concentrations ranged from 15.0 to 24.3 ng/m^3 at 5 m from the edge of the treated field and 10.8 to 17.5 ng/m^3 at 50 m from the edge of the field.

The reviewer was able to confirm the modeling conclusions both for deposition and air concentrations. The reviewer also conducted modeling analysis for Little Rock, Arkansas, Nashville, Tennessee, and Springfield, Missouri, attempting to capture modeling results representative of soybean growing regions in Arkansas, Tennessee, and Missouri. Modeling results were comparable to those achieved for the North Carolina, Illinois, and Texas modeling results.

II. Results and Discussion

A. Empirical Flux Determination Method Description and Applicability

Indirect Method

The indirect method, commonly referred to as the "back calculation" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the indirect method, air samples are collected at various locations outside the boundaries of a treated field. Meteorological conditions, including air temperature, wind speed, and wind direction, are also collected for the duration of the sampling event. The dimensions and orientation of the treated field, the location of the samplers, and the meteorological information are used in combination with the AERMOD dispersion model (Version 18081) and a unit flux rate of 0.001 $g/m^2 \cdot s$ to estimate concentrations at the sampler locations. Since there is a linear relationship between flux and the concentration at a given location, the results from the AERMOD model runs are compared to those concentrations actually measured, and a regression is performed, using the modeled values along the x-axis and the measured values along the y-axis. If the linear regression does not result in a statistically significant relationship, the regression may be rerun forcing the intercept through the origin, or the ratio of averages between the monitored to modeled concentrations may be computed, removing the spatial relationship of the concentrations. The indirect method flux back calculation procedure is described in detail in Johnson et al., 1999.

Study authors used a similar analysis to obtain flux rates. However, if, after regression analysis, the linear regression did not result in a statistically significant relationship, instead of rerunning the regression by forcing the intercept through zero, the spatial relationship was removed by sorting both the measured and modeled air concentrations (independently) in ascending order, then redoing the regression, with the final flux estimate calculated as the slope of this alternative regression multiplied by the nominal flux. If the sorted regression was also not statistically significant, the ratio of the sum of the measured concentrations to the sum of the modeled concentrations was multiplied by the nominal flux to get the final flux estimate.

Aerodynamic Method

The aerodynamic method, also referred to as the "flux-gradient" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the aerodynamic method, a mast is erected in the middle of the treated field and concentration samples are typically collected at four or five different heights, ranging from 0.5 to 10 feet. Likewise, temperature and wind speed data are collected at a variety of heights. A log-linear regression is performed relating the natural logarithm of the sample height to the concentration, temperature, and wind speed. These relationships are then incorporated into an equation to estimate flux. The methods to estimate flux and related equations are presented in Majewski et al., 1990. The equation for estimating flux using the aerodynamic method is Thornthwaite-Holzman Equation, which is shown in the following expression:

Equation 1 $$P = \frac{k^2(\Delta\bar{c})(\Delta\bar{u})}{\phi_m \phi_p [\ln\left(\frac{z_2}{z_1}\right)]^2}$$

where P is the flux in units of $\mu g/m^2 \cdot s$, k is the von Karman's constant (dimensionless ~0.4), $\Delta\bar{c}$ is the vertical gradient pesticide residue concentration in air in units of $\mu g/m^3$ between heights z_{top} and z_{bottom} in units of meters, $\Delta\bar{u}$ is the vertical gradient wind speed in units of m/s between heights z_{top} and z_{bottom}, and ϕ_m and ϕ_p are the momentum and vapor stability correction terms respectively. Following the conditions expected in the neutrally stable internal boundary layer characterized by an absence of convective (buoyant) mixing but mechanical mixing due to wind shear and frictional drag, a log-linear regression is performed relating the natural logarithm of the sample height to the concentration, temperature, and wind speed. The adjusted values of the concentration, temperature, and wind speed from this regression is incorporated into Equation 1 to arrive at Equation 2 which is ultimately used to compute the flux.

Equation 2 $$Flux = \frac{-(0.42)^2(c_{ztop} - c_{zbottom})(u_{ztop} - u_{zbottom})}{\phi_m \phi_p \ln\left(\frac{z_{top}}{z_{bottom}}\right)^2}$$

where ϕ_m and ϕ_p are internal boundary layer (IBL)stability correction terms determined according to the following conditions based on the calculation of the Richardson number, R_i:

Equation 3 $$R_i = \frac{(9.8)(z_{top} - z_{bottom})(T_{ztop} - T_{zbottom})}{\left[\left(\frac{T_{ztop} + T_{zbottom}}{2}\right) + 273.16\right] + (u_{ztop} - u_{zbottom})^2}$$

where T_{ztop} and $T_{zbottom}$ are the regressed temperatures at the top and bottom of the vertical profile in units of °C.

if $R_i > 0$ (for Stagnant/Stable IBL)
$$\phi_m = (1 + 16R_i)^{0.33} \; and \; \phi_p = 0.885(1 + 34R_i)^{0.4}$$

if $R_i < 0$ (for Convective/Unstable IBL)
$$\phi_m = (1 - 16R_i)^{-0.33} \; and \; \phi_p = 0.885(1 - 22R_i)^{-0.4}$$

The minimum fetch requirement is that the fetch should be at least 100 times the highest height of the air sampler for this method to be valid. Given the highest height sampled was 1.67 m (1.5 m above the crop which was 17 cm), the minimum fetch distance is 167 m. Based on wind direction analysis, this requirement was not satisfied at all times. The minimum fetch during the conduct of the study was 151 m, which is about 10% below the minimum fetch requirement. As such, there is some uncertainty in the flux rates derived from this analysis, as the internal boundary layer depth may not have been sufficient. The aerodynamic method used to estimate flux and related equations are presented in Majewski et al., 1990.

Integrated Horizontal Flux Method

The integrated horizontal flux method, also referred to as the "mass balance" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the integrated horizontal flux method, a mast is erected in the middle of the treated field and concentration samples are typically collected at four or five different heights, ranging from approximately 0.5 to 5 feet. Likewise, wind speed data are collected at a variety of heights. A log-linear regression is performed relating the natural logarithm of the sample height to the air concentration and wind speed following the log law relationships for the atmospheric boundary layer. These relationships are then incorporated into an equation to estimate flux. The methods to estimate flux and related equations are presented in Majewski et al., 1990. The equation for estimating flux using the integrated horizontal flux method is the following expression:

Equation 4 $$P = \frac{1}{x}\int_{Z_0}^{Z_p} \overline{c}\overline{u}\,dz$$

where P is the volatile flux in units of µg/m^2·s, $\bar{c}$ is the average pesticide residue concentration in units of µg/m^3 at height Z in units of meters, $\bar{u}$ is the wind speed in units of m/s at height Z, x is the fetch of the air trajectory blowing across the field in units of meters, Z_0 is the aerodynamic surface roughness length in units of meters, Z_p is the height of the plume top in units of meters, and dz is the depth of an incremental layer in units of meters. Following trapezoidal integration, equation 4 is simplified as follows in equation 5 (Yates, 1996):

Equation 5 $$P = \frac{1}{x}\sum_{Z_0}^{Z_P}(A * Ln(z) + B) * (C * Ln(z) + D)dz$$

where A is the slope of the wind speed regression line by ln(z), B is the intercept of the wind speed regression line by ln(z), C is the slope of the concentration regression by ln(z), D is the intercept of the concentration regression by ln(z), z is the height above ground level. Z_p can be determined from the following equation:

Equation 6 $$Z_P = \exp\left[\frac{(0.1 - D)}{C}\right]$$

The minimum fetch requirement of 20 meters for this method to be valid was satisfied at all times. The surface characteristics of the field consisted of soybeans at a height of 17 cm. The surface roughness length, estimated using AERSURFACE, was 0.08 m, below the required of 0.1 meters for this method to be valid.

B. Temporal Flux Profile

The flux determined from the registrant and reviewer for each sampling period after the application is provided in **Tables 6** and **7**. The pH of the tank mix was 4.85 prior to application.

Table 6. Field volatilization flux rates of dicamba obtained in study – Indirect Method

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer ($\mu g/m^2 \cdot s$)	Notes	Registrant ($\mu g/m^2 \cdot s$)	Notes
1	6/22/19 14:51 – 18:54	4:03	0.001855	Regression	0.003130	A
2	6/22/19-6/23/19 18:12 – 7:56	13:44	0.000472	Regression no intercept	0.000426	B
3	6/23/19 7:19 – 18:47	11:28	0.000716	Regression	0.000716	B
4	6/23/19-6/24/19 18:17 – 20:28	26:11	0.000072	Regression no intercept	0.000161	A, C
5	6/24/19-6/25/19 18:56 – 9:30	14:34	0.000000	D	0.000000	D
6	6/25/19 8:10 – 20:25	12:15	0.000000	D	0.000000	D
7	6/25/19-6/26/19 19:05 – 10:00	14:55	0.000000	D	0.000000	D
8	6/26/19 8:07 – 18:59	10:52	0.000000	D	0.000000	D
9	6/26/19-6/27/19 18:20 – 8:46	14:26	0.000000	D	0.000000	D
10	6/27/19 7:39 – 18:48	11:09	0.000080	Regression no intercept	0.000110	A
11	6/27/19-6/28/19 18:12 – 8:56	14:44	0.000005	Regression no intercept	0.000002	E
12	6/28/19 7:59 – 19:06	11:07	0.000196	Regression no intercept	0.000334	E
13	6/28/19-6/29/19 18:07 – 8:13	14:06	0.000011	Regression no intercept	0.000007	E

Data obtained from Appendix B, Table 5, pp. 127-128 and Appendix D, Table 6, p. 555 of the study report.

Notes

- A The ratio method was used to calculate the flux estimate for the sampling period.
- B The spatial regression method was used to calculate the flux estimate for the sampling period.
- C Samples from stations G and H were not collected, as the samples were compromised due to the storm. The sample from station C was collected after the other samples and had a duration of 37:27, so it was not used in the flux rate calculations.
- D All observed concentrations for period are <LOD or considered 0.0 $\mu g/m^3$. The flux assumed 0.0 $\mu g/m^2/s$.
- E The sorted regression method was used to calculate the flux estimate for the sampling period.

Table 7. Field volatilization flux rates of dicamba obtained in study – Integrated Horizontal Flux and Aerodynamic Methods

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer (μg/m²·s)	Registrant (μg/m²·s)	Empirical Flux Determination Method*	Notes
1	6/22/19 15:05 – 18:07	3:02	0.001367 0.004534	0.001406 0.003920	IHF AD	
2	6/22/19-6/23/19 18:13 – 7:26	13:13	0.000444 0.000425	0.000444 0.000423	IHF AD	
3	6/23/19 7:28 – 18:24	10:56	0.000348 0.001430	0.000348 0.001442	IHF AD	
4	6/23/19-6/24/19 18:26 – 19:07	24:41	0.000035 0.000728	NC NC	IHF AD	A
5	6/24/19-6/25/19 19:10 – 8:46	13:36	0.000000 0.000000	0.000000 0.000000	IHF AD	B
6	6/25/19 8:51 – 19:15	10:24	0.000000 0.000000	0.000000 0.000000	IHF AD	B
7	6/25/19-6/26/19 19:32 – 7:58	12:26	0.000000 0.000000	0.000000 0.000000	IHF AD	B
8	6/26/19 8:05 – 18:26	10:21	0.000000 0.000000	0.000000 0.000000	IHF AD	B
9	6/26/19-6/27/19 18:29 – 7:44	13:15	0.000000 0.000000	0.000000 0.000000	IHF AD	B
10	6/27/19 7:48 – 18:46	10:58	0.000097 0.000001	0.000097 0.000001	IHF AD	
11	6/27/19-6/28/19 18:55 – 8:05	13:10	0.000025 0.000000	0.000028 0.000000	IHF AD	
12	6/28/19 8:13 – 18:08	9:55	0.000011 0.000119	0.000011 0.000121	IHF AD	
13	6/28/19-6/29/19 18:18 – 7:58	13:40	0.000000 NC	0.000000 NC	IHF AD	C

Data obtained from Appendix B, Table 5, pp. 127-128; Appendix D, Table 8, p. 557; and Appendix D, Table 10, p. 560 of the study report.
NC indicates not calculated.
*Methods legend: AD = Aerodynamic Method, IHF = Integrated Horizontal Flux.
Notes
A PUF samples were contaminated by treated soil via rain splash during a precipitation event. Flux was not calculated for this period by study authors.
B All sample residues collected during these periods were ND or <LOD.
C Due to a reversed concentration gradient, no flux was calculated for this period by the aerodynamic method.

Due to a thunderstorm and heavy rainfall, some samples during period 4 were not collected, and others were contaminated by treated soil via rain splash. Flux rates were not calculated via the integrated horizontal flux or aerodynamic methods for this sampling period by the study authors. Flux rates calculated via the indirect method for period 4 are for a *ca.* 24-hour period including both day and night conditions.

All measured concentrations at the center mast and perimeter samplers for periods 5 through 9 were either non-detect or less than the LOD. Flux rates for these periods were estimated to be 0.0 $\mu g/m^2 \cdot s$. It is uncertain how much dicamba remained on the field after the heavy thunderstorm that occurred during period 4 such that there would have been little to no dicamba left to volatilize.

Air concentrations at the center mast for period 13 showed a reversed gradient with height resulting in a flux of 0.0 $\mu g/m^2 \cdot s$ for the period.

For the indirect method, R-squared values for the study author generated linear regressions of modeled and measured air concentrations ranged from 0.706 for period 11 to 0.965 for period 2. R-squared values for the reviewer generated linear regressions of modeled and measured air concentrations ranged from 0.33 for period 12 to 0.965 for period 2. Study authors used spatial or sorted regressions to estimate flux during periods 2, 3, 11, 12, and 13 and the ratio method to estimate flux during periods 1, 4, and 10.

For the aerodynamic and integrated horizontal flux methods, R-squared values in log-linear vertical profiles of wind speed were generally high with all r-squared $\geq$ 0.980 (Appendix D, Table 8, p. 557 and Appendix D, Table 10, p. 560). R-squared values in log-linear vertical profiles of concentration were low for periods 3 (0.679 to 0.713), 10 (0.027 to 0.031), and 11 (0.001 to 0.002). R-squared values in log-linear vertical profiles of temperature were less than 0.7 for periods 2 (0.105), 4 (0.467), 5 (0.248), 7 (0.317), 9 (0.285), 11 (0.000), and 13 (0.031). It should be noted that most of these periods occurred overnight, when a log-linear vertical profile of temperature typically does not occur.

The maximum flux rate calculated by all three methods occurred during the initial sampling period after application. Maximum flux rates were 0.001855 $\mu g/m^2 \cdot s$, 0.001369 $\mu g/m^2 \cdot s$, and 0.004534 $\mu g/m^2 \cdot s$ for the indirect, integrated horizontal flux, and aerodynamic methods, respectively. Flux rates estimated by the study authors typically matched those developed by the reviewer.

C. Spray Drift Measurements

Spray drift measurements indicated that dicamba residues were detected at a maximum fraction of the applied of 0.002904 at 3 m from the field within the first hour after application (Appendix F, Table 1, p. 655). Dicamba residues were not detected in any of the upwind or right wind samples within the first hour after application. **Figures 4** and **5** depict the deposition fractions and the reviewer-predicted spray drift curves for the downwind and left wind transects within the first hour after application.

To develop the deposition curves, data were fit to a modified Morgan-Mercer-Floden function, similar to how spray drift deposition estimates were derived for the AgDRIFT, ground application model.

$$f = \frac{1}{(1 + ad)^b}$$

where f is the fraction of the application rate at distance d (m). The fitted parameters are a and b, where a is the 'slope' parameter and b is the curvature of the function. Typically, the fitted equation would include a term to account for the deposition from each swath. However, as the path of application was not always perpendicular to the deposition collectors, this term was removed from the equation. The coefficients were obtained by fitting the field data for the various transects.

Figure 4 Spray Drift Analysis for Downwind Transects – 1 Hour

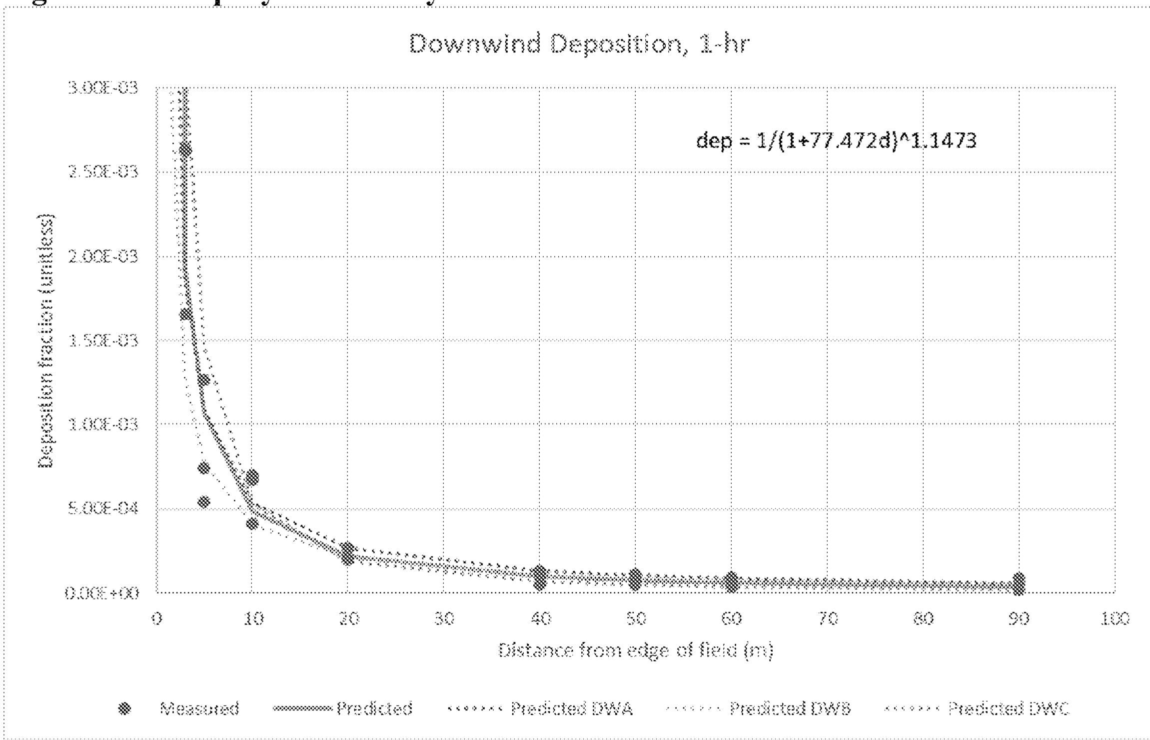
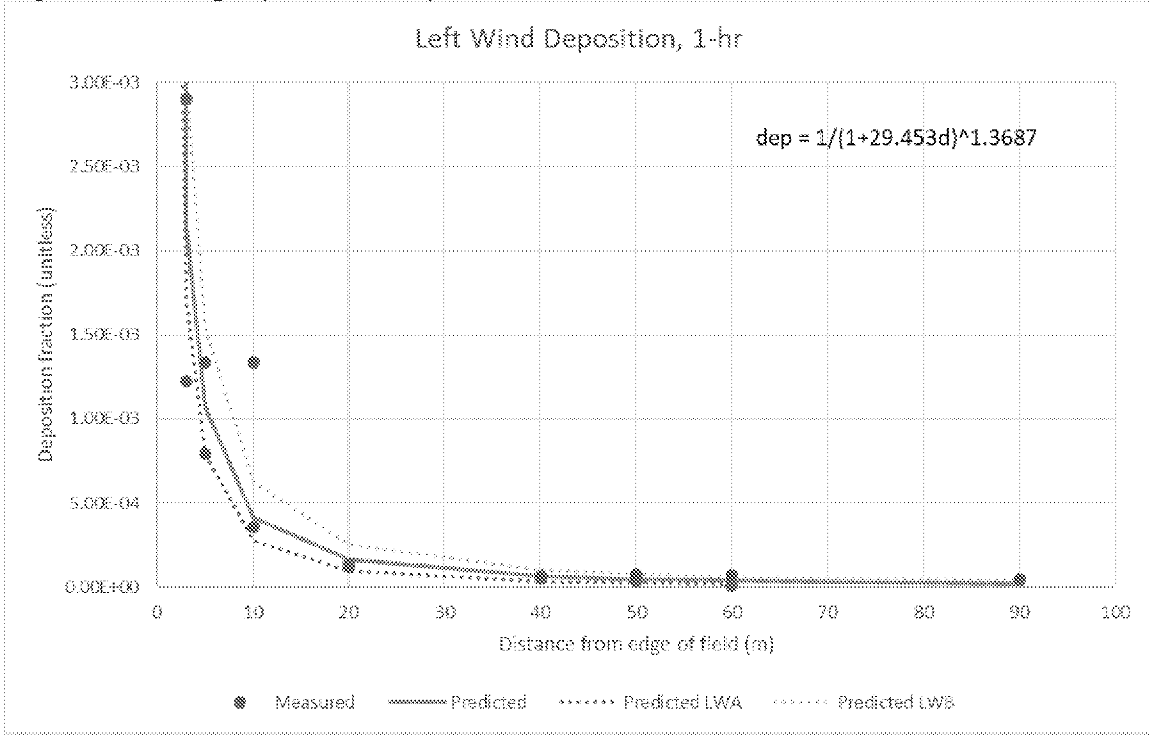


Figure 5 Spray Drift Analysis for Leftwind Transects – 1 Hour



Study authors derived deposition curves using four non-linear regression models for each transect (Appendix F, pp. 649-650). For the samples collected within the first hour of application, the best fit models were the power with coefficient and intercept model (downwind transect A and left wind transect B) and the biexponential model (downwind transects B & C and left wind transect A; Appendix F, Table 2, p. 668). The curves were similar to those generated by the reviewer.

Estimated distances from the edge of the field to reach NOAEC for soybeans (2.6×10^{-4} lb ae/A, or a deposition fraction of 5.2×10^{-4}) were (7.7 to 10.4 m for the three transects) and 8.5 m (6.6 to 11.5 m for the two transects) in the downwind and left wind directions, respectively, using the reviewer-developed curves and ranged from 5.2 to 13.2 m and 7.4 to 15.2 m in the downwind and left wind directions, respectively, for the study author developed curves.

D. Plant Effects Results

Spray Drift + Volatility Exposure Transects

Plant Height

The reviewer found significant inhibitions of plant height along downwind (DW), left wind (LW) and northeast transects. The reviewer evaluated each of the observed transects independently using logistic regression methods in Excel (Figures 6, 8 & 10). The best fit regression (as indicated by the R^2) for each transect were used to estimate the distance at which a 5% reduction in plant height would be predicted based on the comparison to the mean plant height from control plots. Control plots "UCE" and "UCF" were not included in the evaluation

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because the study author indicated there were significant visual signs of injury (VSI; 30-40%) for these two plots. Table 6b provides the estimated distances to 5% reduction in plant height for each transect. The furthest distances were estimated for transects in the Down Wind, Left Wind, and NE transect areas, reaching out to distances of 11 to 68 meters (36 to 221 feet).

Flooding was reported to have impacted DWA, DWB, DWC, SW and UWB transects. The impact of this on plant height effects is uncertain. The study report provided a summary of plant height variation over time for each transect as it related to control mean plant height. Plant height at the beginning of the study was not significantly different across the field based on these summaries of the data (Appendix G, Figures 8A-F). Over successive sampling periods, the plants nearest the field began to deviate from the mean control response with lower growth rates, while plants at the furthest extent of the transects were relatively similar in height to the controls. The field height discussion and figures (Appendix G, Figure 7A) does not provide convincing evidence that flooding would cause a dose response pattern within a transect. Therefore, the dose response pattern from the edge of the field to the furthest plots along these transects and over time, plus the fact that this response was consistent across flooded and non-flooded transects, the impact of flooding is considered non-significant for plant height effects, and reduced plant height effects are considered attributed to the dicamba exposure during application.

A major uncertainty in the implementation of this study was that the measurements of plant height were not consistently taken from the same individual plants over the course of the successive sampling events. While the study authors indicate that the initial plot distances were selected to reduce variability in plant height at the start of the study, it is unclear how the transects relate to the rest of the field, and more importantly how other plants in the plot were responding as compared to those that were selected “non-systematically” for measurement of plant height. No discussion was provided to explain how the plants were selected such to prevent selection of the healthiest looking plants from a plot. This uncertainty may contribute to underestimation of effects and therefore underestimation of off-field distance estimates.

Visual Signs of Injury (VSI)

Visible symptomology was reported, but the specific phytotoxic symptoms were not detailed for the transects. For the drift study, two of the downwind transects, two of the left-side wind transects, and the northeast transect showed a dose-response relationship between percent of visual symptoms and distance to the treatment field. For these transects, linear, logistic and polynomial regression methods in Excel to estimate the distance to the point where 20% VSI would be predicted (Figures 7, 9 & 11). The furthest distances to 10% VSI were consistent with the transects that showed significant effects on plant height and ranged from 44.0 meters to 109.0 meters (144.4 to 357.6 feet; Table 6b). Transects DWC and UWB did not show a significant dose response with distance. For these two transects, it is unclear if this lack of dose response is reflective of the flooding condition or dicamba exposure through drift.

Volatility Exposure (covered) Transects

Plant height measures and distances estimated with logistic regression, indicate that impacts to plant height were significantly less than observed along the uncovered transects. Effects were observed along DWA, DWB, RWA, RWB, and UWB transects with a maximum 5% effect distance estimated at 16 meters (52 feet; Table 6b). Several transects observed 10% or greater VSI across the entire transect length.

Table 6b. Estimated distance to 5% reduction in plant height and visual signs of injury.

Exposure Pathway	Spray Drift + Volatility (uncovered transects)		Volatility (covered transects)	
Transect	Distance to 5% Height (meters)	Distance to 10% VSI (meters)	Distance to 5% Height (meters)	Distance to 10% VSI (meters)
DWA[a]	56.2[e]	109.0[c]	13.7[e]	>20[f]
DWB[a]	58.8[e]	91.8 [b,d]	16.0[e]	>20[f]
DWC[a]	67.3[e]	>90 [b,f]	-	-
LWA	16.1[e]	48.7[e]	<5[f]	<3[f]
LWB	11.1[e]	50.4 [c]	>5[f]	<3[f]
NE	22.1[e]	44.0 [e]	-	-
RWA	<10[f]	<3[f]	2.8[e]	<3[f]
RWB	<10[f]	<3[f]	7.8[e]	<3[f]
SE	<10[f]	<3[f]	-	-
SW	>60[f]	<3[f]	-	-
UWA	<10[f]	<3[f]	<5[f]	<3[f]
UWB[a]	>60[f]	>90[b,f]	12.2[e]	>20[f]

[a] Study authors indicate flooding may have impacted these transects
[b] DWC Injury showed a shallow dose response with effects ranging from 50% at 5 meters to 35% at 90 meters. UWB injury ranged from 20-25% for the extent of the transect.
[c] distance estimated with linear regression
[d] distance estimated with polynomial regression
[e] distance estimated with logistic regression
[f] distance estimated visually

Figure 6: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "Downwind Transects".

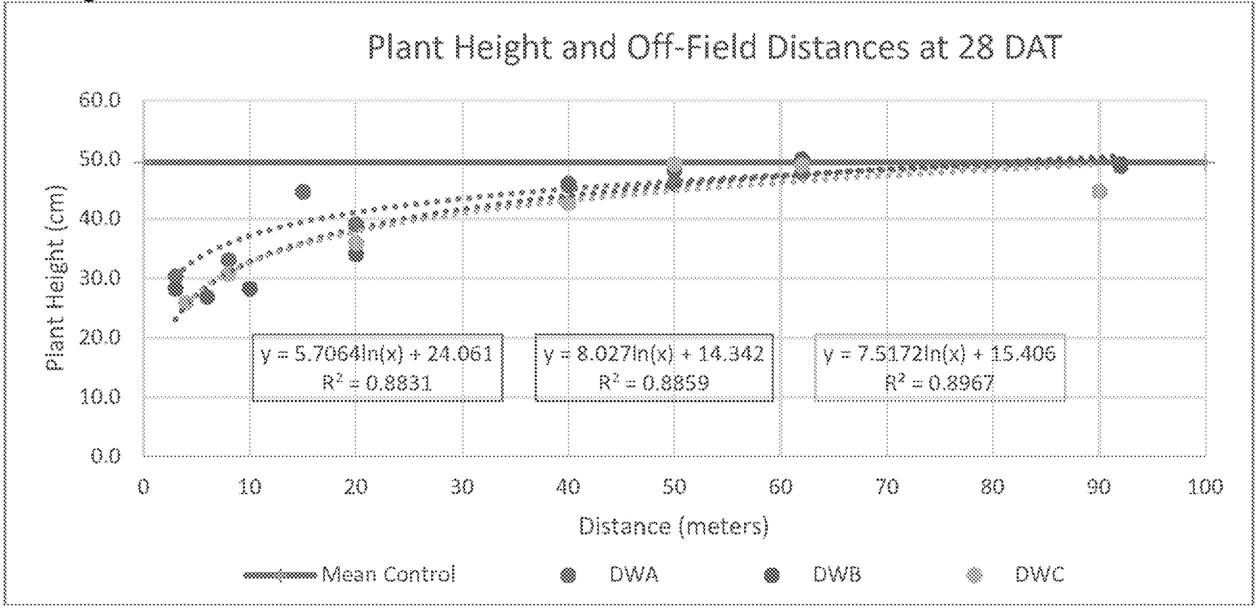


Figure 7: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "Downwind Transects".

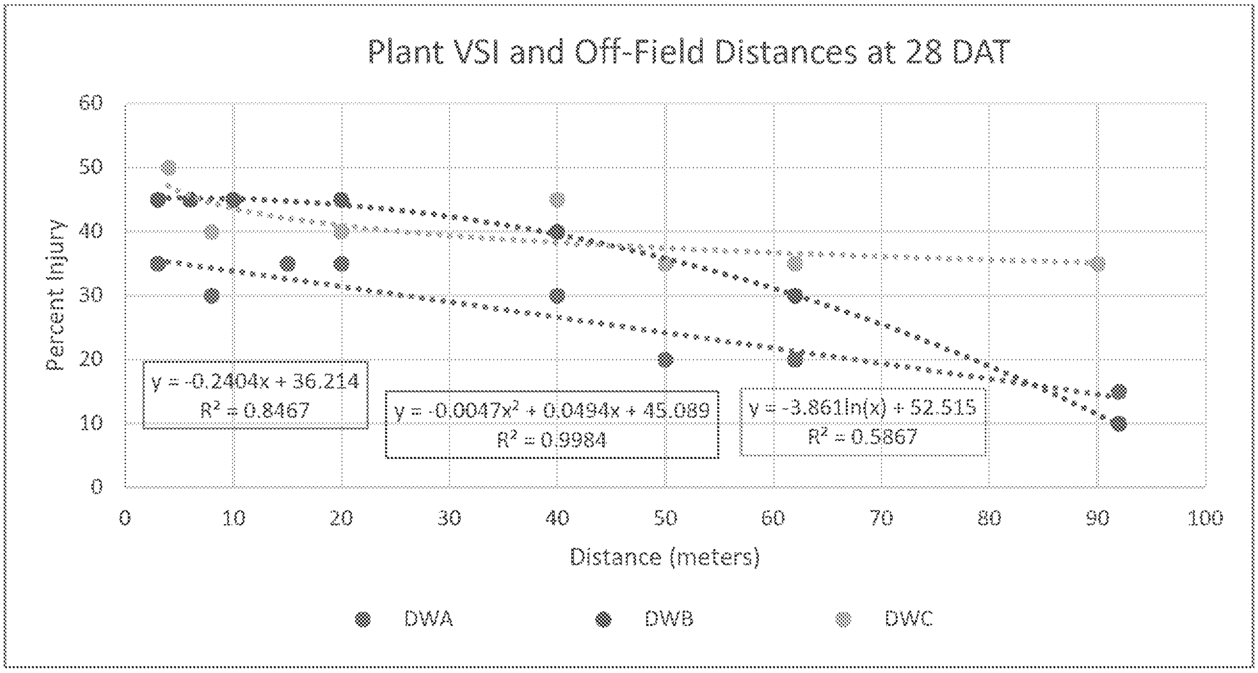


Figure 8: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "Left Wind" and "Northeast" corner transects.

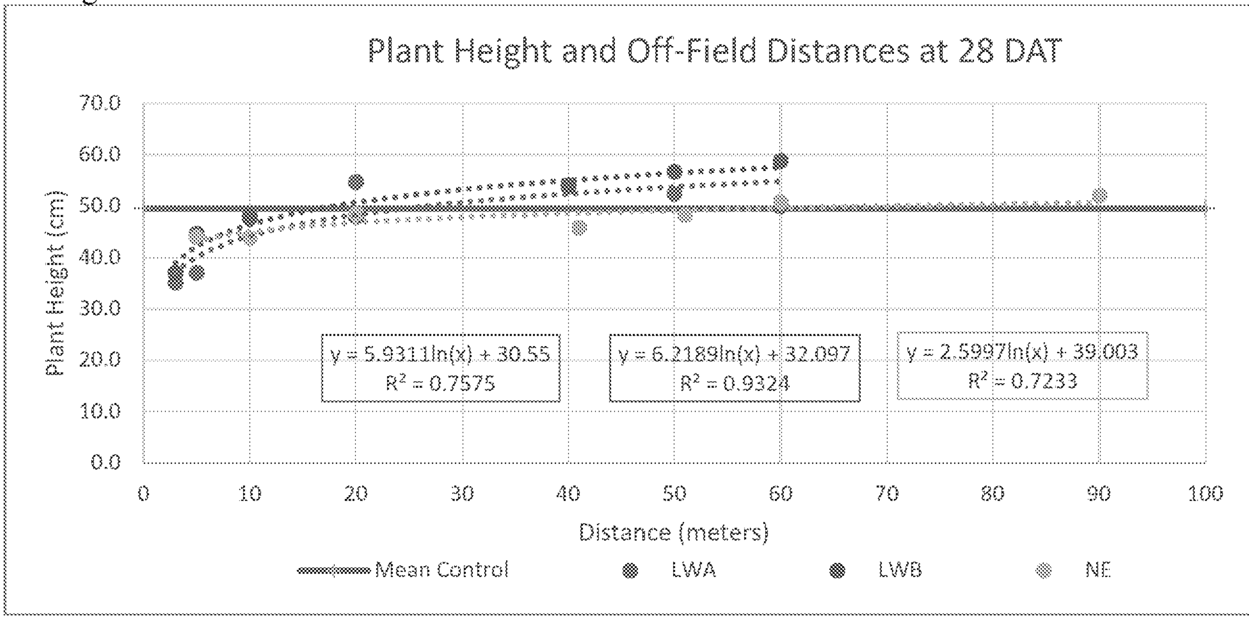


Figure 9: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "Left Wind" and "Northeast" corner transects.

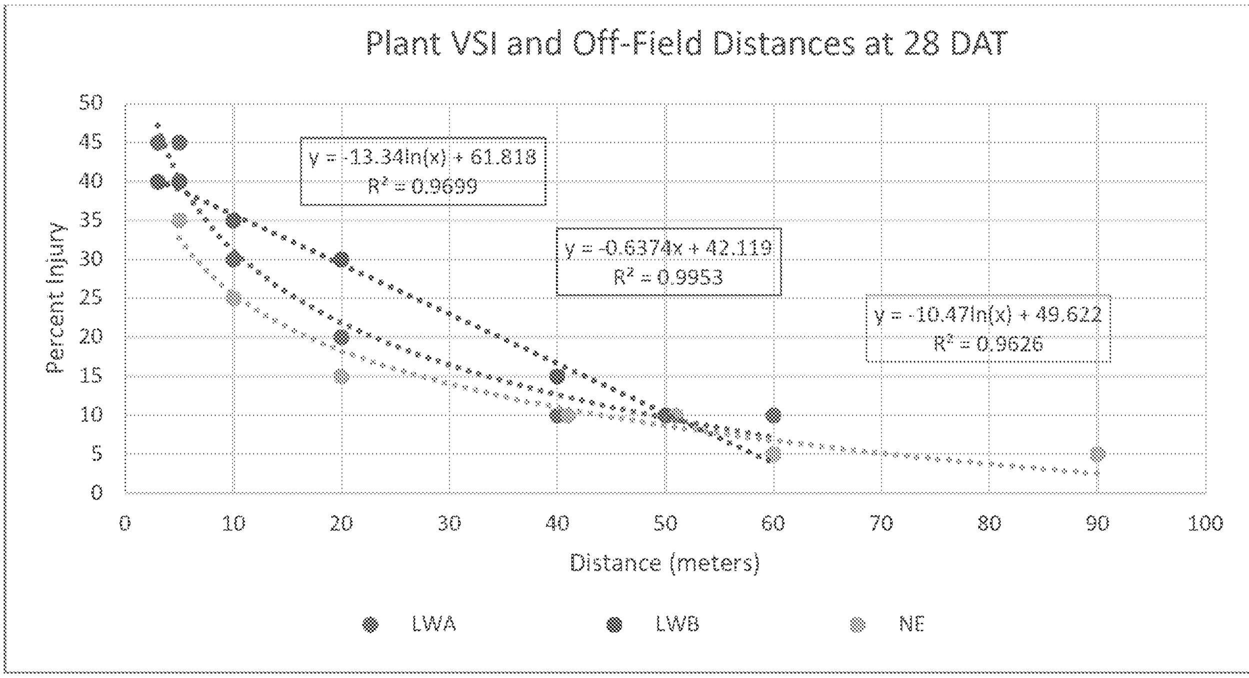


Figure 10: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "Up Wind" and "Southwest" corner transects.

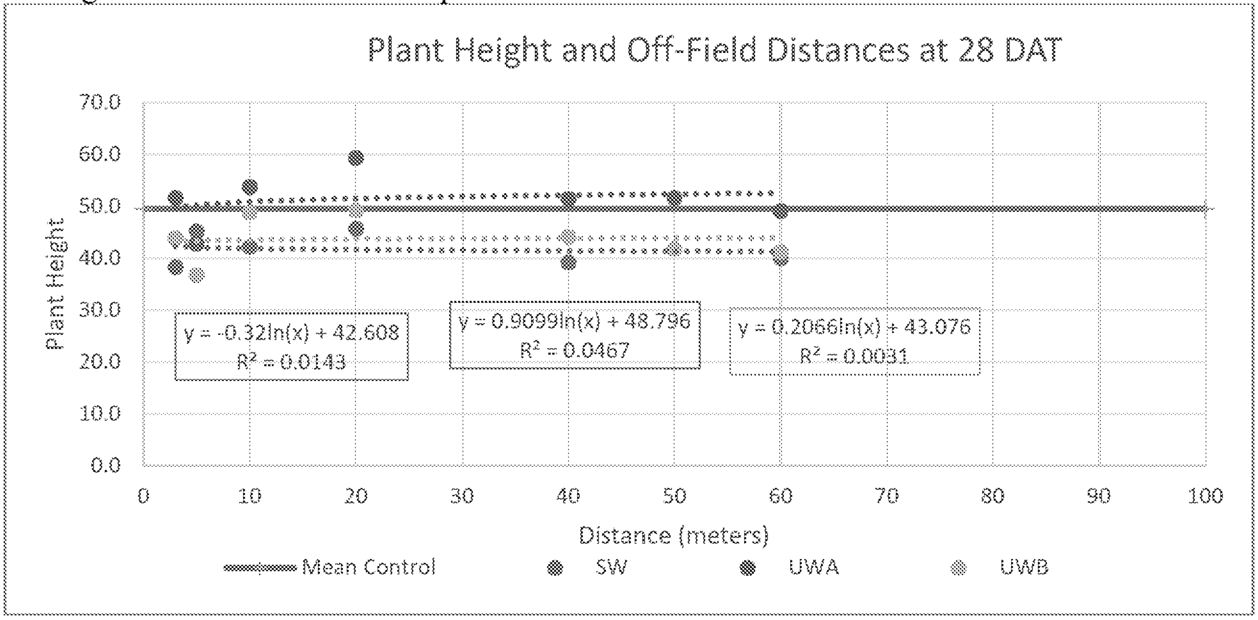
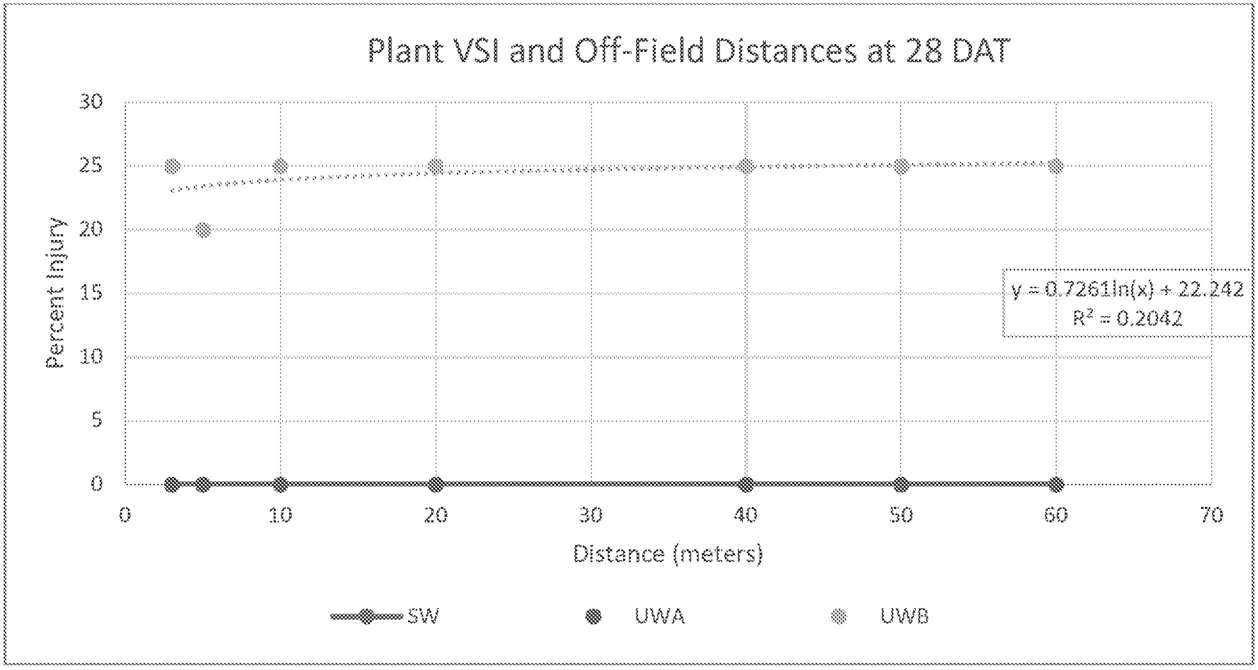


Figure 11: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "Up Wind" and "Southwest" corner transects. Note: SW and UWA transects showed no VSI.



III. Study Deficiencies and Reviewer's Comments

1. Due to a calculation error, the tank mix was depleted prior to completing the application. No dicamba was applied to the final 1.33 acres of the *ca.* 25 acre plot (p. 18).

2. A thunderstorm destroyed all spray drift deposition filter paper samples from the 24 to 48-hour post-application sampling periods (p. 17). Associated flooding prevented the deployment and collection of 48 to 60-hour PUF samples. Two perimeter PUF samples were not collected for the 60 to 72-hour period as well. Some 48 to 72-hour spray drift deposition samples were not deployed or collected. Lastly, PUF samples periods 5 through 9 (Hours 48-112) registered concentrations below the level of detection, resulting in uncertainty in whether the emissions after hour 24 were representative of a typical soybean field treated in Mississippi.

3. When conducting the indirect flux rate analysis, study authors removed samples from the analysis when the dicamba was detected below the LOD (0.3 ng/PUF) but retained samples that had no observable peak or observed residues. Samples below the LOD should be retained as well and set to half the detection limit when estimating flux rates.

4. The slopes calculated by the study authors for wind speed (Appendix D, Table 8, p. 557) for the integrated horizontal flux method used a linear regression and not log-linear. The regressions did not significantly impact the wind speed regressions.

5. The registrant used a different approach to calculate Z_p, the top of the concentration plume, than that recommended by EPA when calculating volatilization flux rates using the Integrated Horizontal Flux method (Appendix D, p. 535). The registrant used:

$$Z_p = \exp\left(\frac{-D}{C}\right)$$

   C and *D* are the slope and intercept of the log-linear concentration regression and removed the 0.1 from the equation. The 0.1 represents the concentration at the top of the plume, which is a carryover from the use of this technique for estimating flux rates for fumigants, which typically have much higher concentrations than those anticipated for semi-volatile chemicals like dicamba. The revised equation is acceptable to the reviewer and does not significantly impact the estimate of flux rates.

6. The study was conducted in compliance with U.S. EPA Good Laboratory Practice requirements with exceptions related to test site observations, slope estimates, application summary and spray rate data, soil taxonomy, calibrator serial numbers, filter paper deployment and collection times, study weather data, and pesticide and crop history (p. 4).

7. The first air monitoring period started after the conclusion of application.

8. Analytical method validation was performed, but the method was not independently validated. A method validation study should be completed from an independent

laboratory separate from and prior to the analysis of the test samples to verify the analytical methods.

9. Soil was characterized (Appendix B, pp. 108, 117-118, and Appendix B, Table 3, p. 125), but no taxonomic classification was provided.

10. Soil bulk density and organic matter content were only reported at a single depth of 0-6 inches.

Study Deficiencies: Plant Effects

1. For both the volatility and spray drift portions of the study, the study author stated that the application area and surrounding test plots were selected to be as uniform as possible with respect to slope and soil texture and care taken to minimize variability in crop size (Appendix G, p. 709). "Although attempts were taken to minimize variability, plant vigor and stand condition was variable across the field, particularly the downwind portions of the field" (Figure 4, p. 721; DWA photo taken on day of spray (day 0)).

   The variability in plant vigor and stand condition across the site suggested the results of both studies may have been confounded due to a lack of homogeneous field conditions.

2. For both the volatility and spray drift portions of the study, the study author adjusted the targeted assessment distances to areas where the stand was visually assessed to be more uniform prior to spray application (Appendix G, p. 709). The study author measured the height of a varying number of plants along each transect prior to test material application (volatility n=3-4; drift n=7-8; Appendix G, Table 1, p. 715). Following application, "because of the variability in the plant height and stand condition, actual measurements distances differed from the target distances for some transects", although actual distances were recorded (Appendix G, p. 708). "At each distance along each transect, ten plants were selected non-systematically with no attempt to measure the same plant at the subsequent time points."

   The method presented by the study author indicates that no effort was made to determine uniform, homogenous, boundary-marked sampling sites at prescribed distances and sampling areas prior to treatment. OCSPP guidance recommends that the integrity of the replicate should be maintained throughout the duration of the study. In this study, plant height was determined for ten different plants at slightly different distances at each sampling interval. Although the study author reported that 'plants selected for plant height measurements were selected non-systemically as an unbiased representation for the population", the reviewer suggests that this sampling method is inadequate and introduces unnecessary variability into the study results that should have been more systematically controlled.

3. A heavy rainfall event of 4.37 inches occurred over the two days following the spray application, inducing flooding and potentially impacting test substance contact time and effects on the soybean plants. Subsequent growth effects due to flooding in some portions

of the test fields were reported. The variable impact of the flooding on plant growth may have additionally confounded test results.

Comparisons of the field transects as they relate to the field elevation did not present convincing evidence that flooding would have impacted the study in the manner by which to exclude transects from the evaluation. For example DW and UW transects run parallel to the elevational gradient, and transects that were reported to be most impacted DWA and DWB represent some of the highest elevations in the field.

From the photos that were included in the study report, the flooding event seemed to be limited in duration. In particular, Figures 5A and 5C show flooding on 6/24/2019 in the UW and DW transect areas and plants appear to have the same condition as pre-flood photos. In an image taken of 6/25 floodwater seems to have receded in the downwind area and plants have a healthier appearance than in many of the other field locations. Figure 15 on page 157 (taken 6/28) shows a dry field. Figure 11 shows a dry field on 6/26/19.

4. For the volatility portion of the study, plastic covers were intended to remain in place for *ca*. 30 minutes post-application before removal (Appendix G, pp. 707-708). According to the study author, the actual time the plants remained covered ranged from *ca*. 1 hour and 45 minutes to 3 hours and 55 minutes (pp. 707-708). The study author stated the reason was due to safety concerns for field personnel due to high heat and humidity. The study author did not specify the time covered for each transect but did omit 14- and 28-day results for DWC (downwind, replicate C) due to plant injury, reportedly from heat. In addition, a small section of the tarp over downwind replicate B blew off potentially exposing the plants to drift spray during application and for 30 minutes post-application, however, no effects of exposure were observed (p. 17).

   Some additional concerns are raised when reviewing Figure 14 (labeled as taken on 6/23/19) and clearly shows that the covers are on the transects. Figure 15 on page 157 (taken 6/28) also shows a covered plot, it is unclear what this plot was attempting to observe, and no mention of the plot was provided in the report.

   The reviewer is concerned that the variability in covered time, the undefined heat build-up, and the unknown impact these factors may have had on plant growth may have confounded treatment effects and rendered the volatility study results invalid. Therefore, the reviewer advises caution in interpretation of the volatility study results.

5. The study author determined No-Effect Distance (NOAED) but did not report the field reference point for calculating no-effect distances. As a result, NOAED values, which include 0 meters and other values reported in Table 2 in the Plant Effects Sub-Report (Appendix G, p. 716, of the study report) should be interpreted with caution.

6. The study author did not provide seed supplier information and historical germination rates for the soybean varieties planted.

7. The control plot was placed upwind of the treatment field. The specific distance upwind from the edge of the field was not reported. Specific plot locations for Control Plots A-F were not reported. Two of the controls were reported to have 30-40 % VSI and were attributed to effects related to flooding. The location and flooding potential could not be evaluated based on the information provided in the report. These two control plots were removed from the evaluation.

8. The north east transect was not evaluated because of poor germination.

9. In a few cases (LWB, LWA, UWB, RWA) the volatility plots did not appear to be placed next to the spray drift plots, and appear to be several meters away in some cases.

10. Drift sampling transects for drift deposition appeared to be several meters away from the DWA, UWB, RWA and RWB transects.

11. Post-application samples were not able to be collected and analyzed because the tank mix was fully depleted by the end of the study due to a calculation error.

12. Pesticides applications to the treatment field and test plots in 2019 were not reported.

13. The physical and chemical properties of the test material were not reported.

References

Johnson, B., Barry, T., and Wofford P. 1999. Workbook for Gaussian Modeling Analysis of Air Concentrations Measurements. State of California, Environmental Protection Agency, Department of Pesticide Regulation. Sacramento, CA.

Maher, D. 2016. Storage Stability of Dicamba on Polyurethane Foam Air Sampling Traps. Monsanto Technical Report MSL0026782. St. Louis, Missouri.

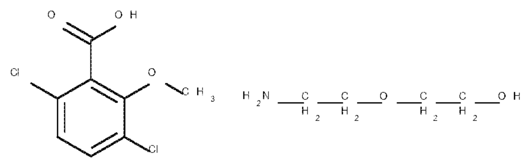
Majewski, M.S., Glotfely, D.E., Paw, K.T., and Seiber, J.N. 1990. A field comparison of several methods for measuring pesticide evaporation rates from Soil. Environmental Science and Technology, 24(10):1490-1497.

Wilson, J.D., and Shum. W.K.N. 1992. A re-examination of the integrated horizontal flux method for estimating volatilization from circular plots. Agriculture Forest Meteor. Vol 57:281-295.

Yates, S.R., F.F. Ernst, J. Gan, F. Gao, and Yates, M.V. 1996. Methyl Bromide Emissions from a Covered Field: II. Volatilization," Journal of Environmental Quality, 25: 192-202.

Attachment 1: Chemical Names and Structures

Dicamba-diglycolamine and Its Environmental Transformation Products. [A]

Code Name/ Synonym	Chemical Name	Chemical Structure	Study Type	MRID	Maximum %AR (day)	Final %AR (study length)
PARENT						
Dicamba-diglycolamine (Diglycolamine salt of dicamba)	IUPAC: 3,6-Dichloro-o-anisic acid-2-(2-aminoethoxy)ethanol CAS: 2-(2-Aminoethoxy)ethanol;3,6-dichloro-2-methoxy-benzoic acid CAS No.: 104040-79-1 Formula: $C_{12}H_{17}Cl_2NO_5$ MW: 326.17 g/mol SMILES: COc1c(Cl)ccc(Cl)c1C(=O)O.NCCOCCO		Field volatility	51017501	NA	NA
MAJOR (>10%) TRANSFORMATION PRODUCTS						
No major transformation products were identified.						
MINOR (<10%) TRANSFORMATION PRODUCTS						
No minor transformation products were identified.						
REFERENCE COMPOUNDS NOT IDENTIFIED						
All compounds used as reference compounds were identified.						

[A] AR means "applied radioactivity". MW means "molecular weight". NA means "not applicable".

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Attachment 2: Statistics Spreadsheets and Graphs

Supporting spreadsheet files accompany the review.

1. Air sampling periods, soil temperature and moisture graphs, and volatility graph

128931_51017501_DE
R-FATE_835.8100_4-1-

2. Validation spreadsheet for the Indirect Method

128931_51017501_DE
R-FATE_835.8100_4-1-

3. Validation spreadsheet for the Integrated Horizontal Flux Method:

128931_51017501_DE
R-FATE_835.8100_4-1-

4. Validation spreadsheet for the Aerodynamic Method:

128931_51017501_DE
R-FATE_835.8100_4-1-

5. Air modeling files

129831 51017501 air modeling.zip

6. Validation spreadsheet for spray drift calculations

128931_51017501_DE
R-Fate_840.1200_08-2'

7. Terrestrial Plants: Regressions for plant height and VSI

MRID21017501_STC -2019-0031_Plant_Da

Attachment 3: Field Volatility Study Design and Plot Map

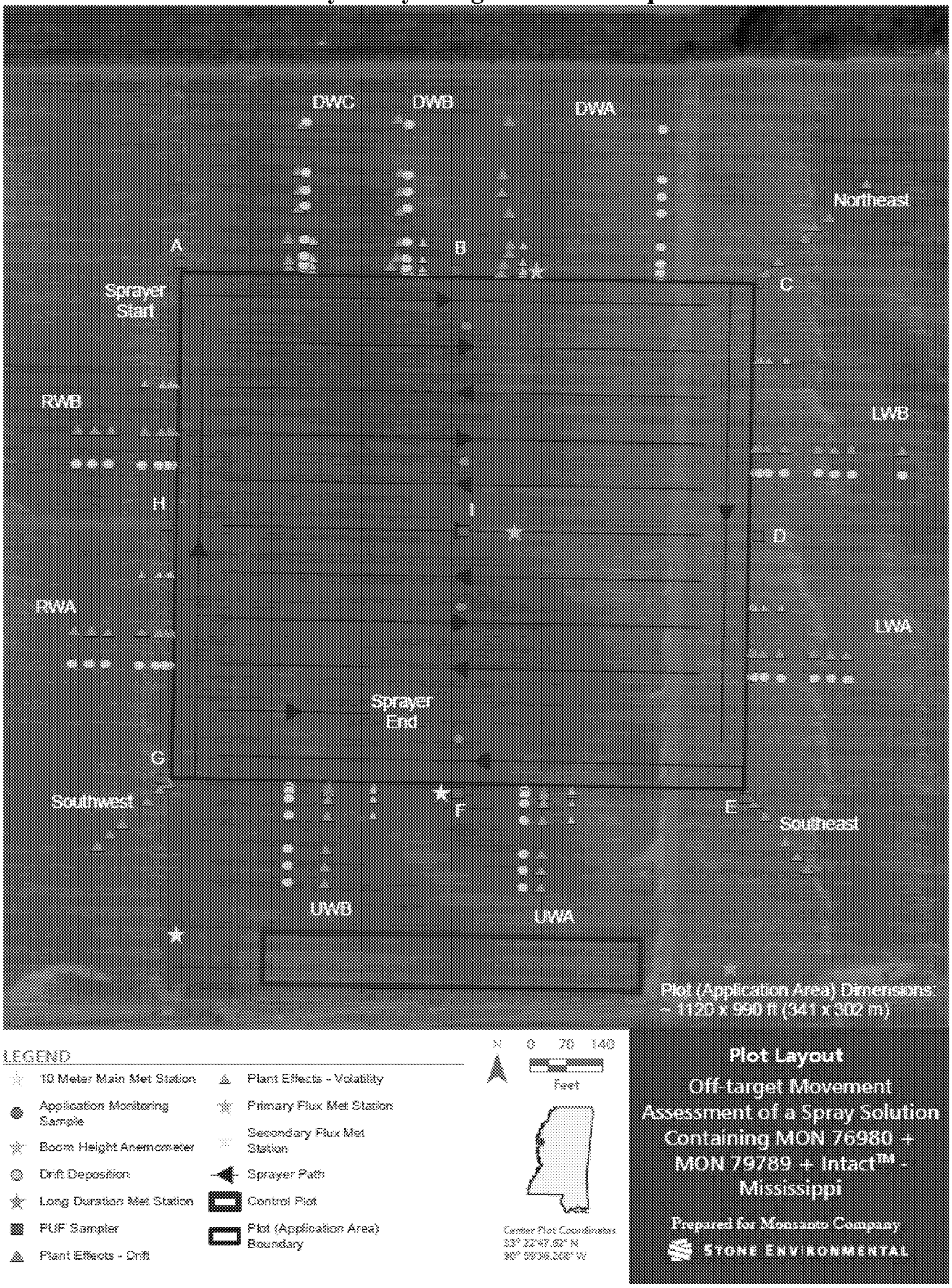

Figure obtained from Appendix B, Figure 2, p. 144 of the study report.